CITY OF
READING
PENNSYLVANIA
BUREAU OF ENGINEERING

Department of Streets and Public Improvements

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JOSEPH F. MITCHELL, P. E.
CITY ENGINEER

October 9, 1992

Vernon Butler RPM
PA Corrective Action Enforcement
US EPA Region III
841 Chestnut Building
Philadelphia, PA 19107

RE: NGK Metals Corporation
Muhlenberg Township, Pennsylvania
EPA RCRA I.D. PAD 04 054 0136

Dear Mr. Butler:

In response to your letter of September 16th last I am forwarding herewith a copy of the requested study as supplied to me by the City's Water Bureau.

As you will note the investigation and report center on the observance of unusual skin lesions on brown bull heads in Lake Ontelaunee. This observation which was given quite a bit of attention in the mid to late 1980's was a cause of concern in that the lake is a major source of drinking water for Reading and surrounding communities.

While the City made considerable efford to relate the fish tumors to some cause, no clear evidence was ever found. In fact, as you will read, similar fish conditions were found in other relatively pristine waters where no significant pollutents were evident.

Never-the-less the City is continuing the study as a part of its potable water system monitoring program. Further evidence, if it is found, will be reported to the appropriate authorities.

If you wish more detail, you might contact the people identified in the enclosed report.

I am available to discuss this matter further if you think it useful.

Very truly yours,

Joseph F. Mitchell

Joseph F. Mitchell, P.E.
City Engineer

cc: E. leonardziak
A. Constantino (215) 320-6251

AR390245

INTRODUCTION

Lake Ontelaunee is a 1,082-acre reservoir in Berks County, Pennsylvania, and is managed as a public water supply source for the city of Reading. The impoundment was formed by the construction of a 42-foot-high earthen dam on Maiden Creek. Most of the lake is open to public fishing (although boating is prohibited) and a portion of the surrounding lands are managed for wildlife by the Pennsylvania Game Commission. Ospreys and various species of waterfowl use the lake.

The Maiden Creek watershed lies within the Valley and Ridge physiographic province (Great Valley section), characterized by open, rolling farmlands. Rocks in this section are comprised primarily of shale and carbonate rocks of Pennsylvanian age (Stamer et al., 1985).

Lake Ontelaunee's 192 square mile watershed is predominantly rural, comprised of farmland and small communities. According to the U.S. Geological Survey (Stamer et al., 1985), 76 percent of land use in the Maiden Creek watershed is agricultural, 21.1 is forested, 1.7 percent is urbanized, and 1.2 percent is in "other" uses such as water and mining. There are three sewage treatment plants, golf courses, a closed municipal waste landfill, mushroom houses, numerous orchards and several foundries located upstream of Lake Ontelaunee.

In 1985, Pennsylvania Fish Commission (PFC) Area Manager Mike Kauffman informed us that he had observed unusual skin lesions on brown bullheads (<u>Ictalurus nebulosus</u>) collected from Lake Ontelaunee during a routine survey. Because the kind of deformities Kauffman described have often been found in brown bullheads exposed to toxic chemicals (such as polycyclic aromatic hydrocarbons) in sediments, we agreed that the situation at Lake Ontelaunee deserved further investigation and conducted field collections of fish from the lake in 1985 and 1987. The following sections detail our methods, results, and implications for future work.

1985 INVESTIGATION

Methods

On April 24, 1985, Service biologist David Putnam met with PFC Area Manager Kauffman at Lake Ontelaunee. The PFC's routine fish studies were in progress, and collection nets had yielded 40 brown bullheads. Collection areas are shown in Figure 1. Mr. Putnam examined the fish and noted that many of the bullheads had lesions and growths on the lip and head area (see Figure 2). In addition, the livers of most of the bullheads appeared to be heavily parasitized. Of 24 brown bullheads examined, Mr. Putnam noted that 15 had some type of apparent physical problems.

Mr. Putnam recorded the lengths and weights of the brown bullheads (see Table A-1), then collected skin and liver samples from 24 brown bullheads and 1 walleye and preserved them in 10 percent buffered formalin. These tissues were then transferred to the Roswell Park Memorial Institute in Buffalo, New York for histopathological examination by Drs. John Black and

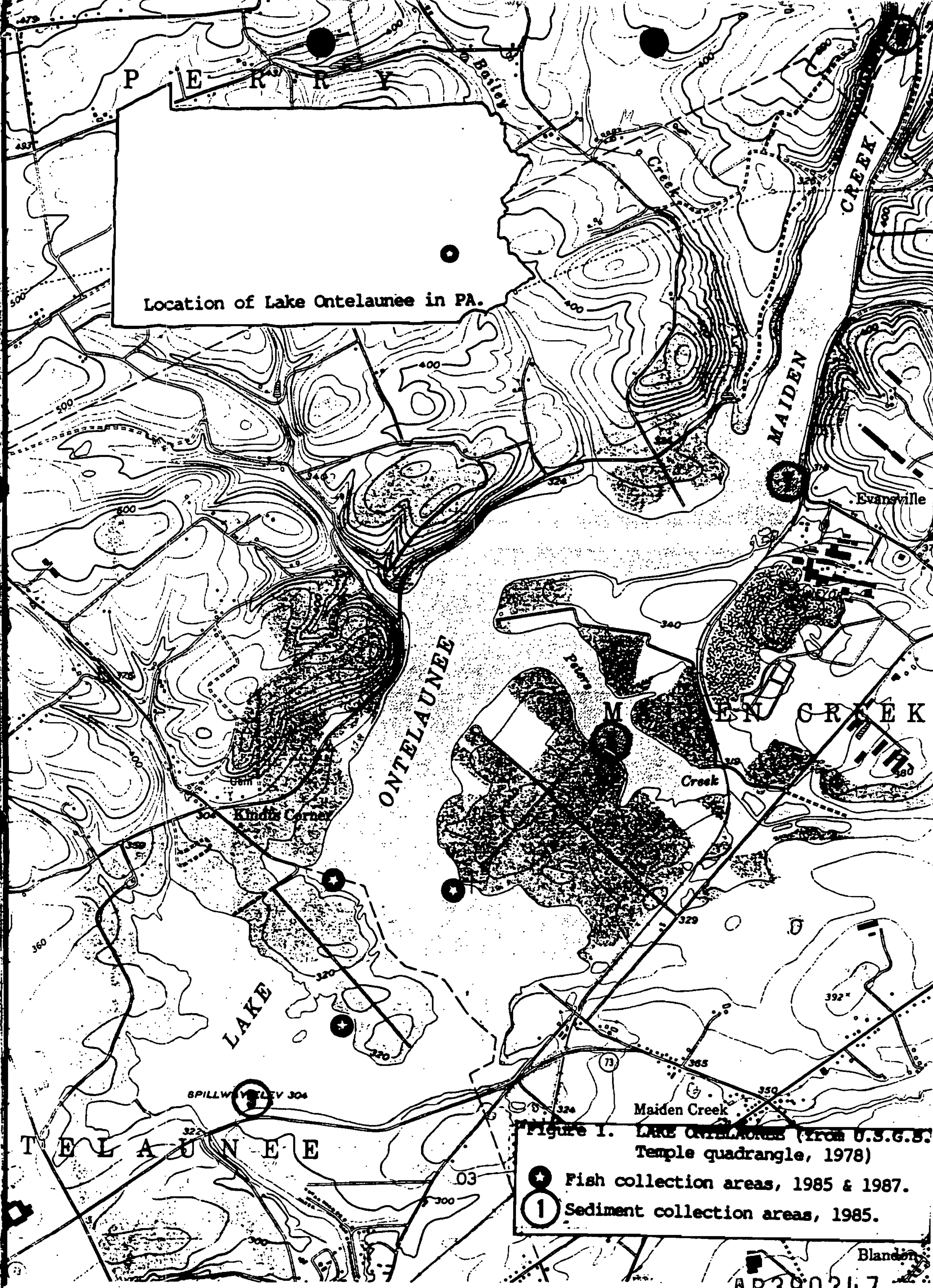

Figure I. LAKE ONTELAUNEE (from U.S.G.S. Temple quadrangle, 1978)

Fish collection areas, 1985 & 1987.

1 Sediment collection areas, 1985.

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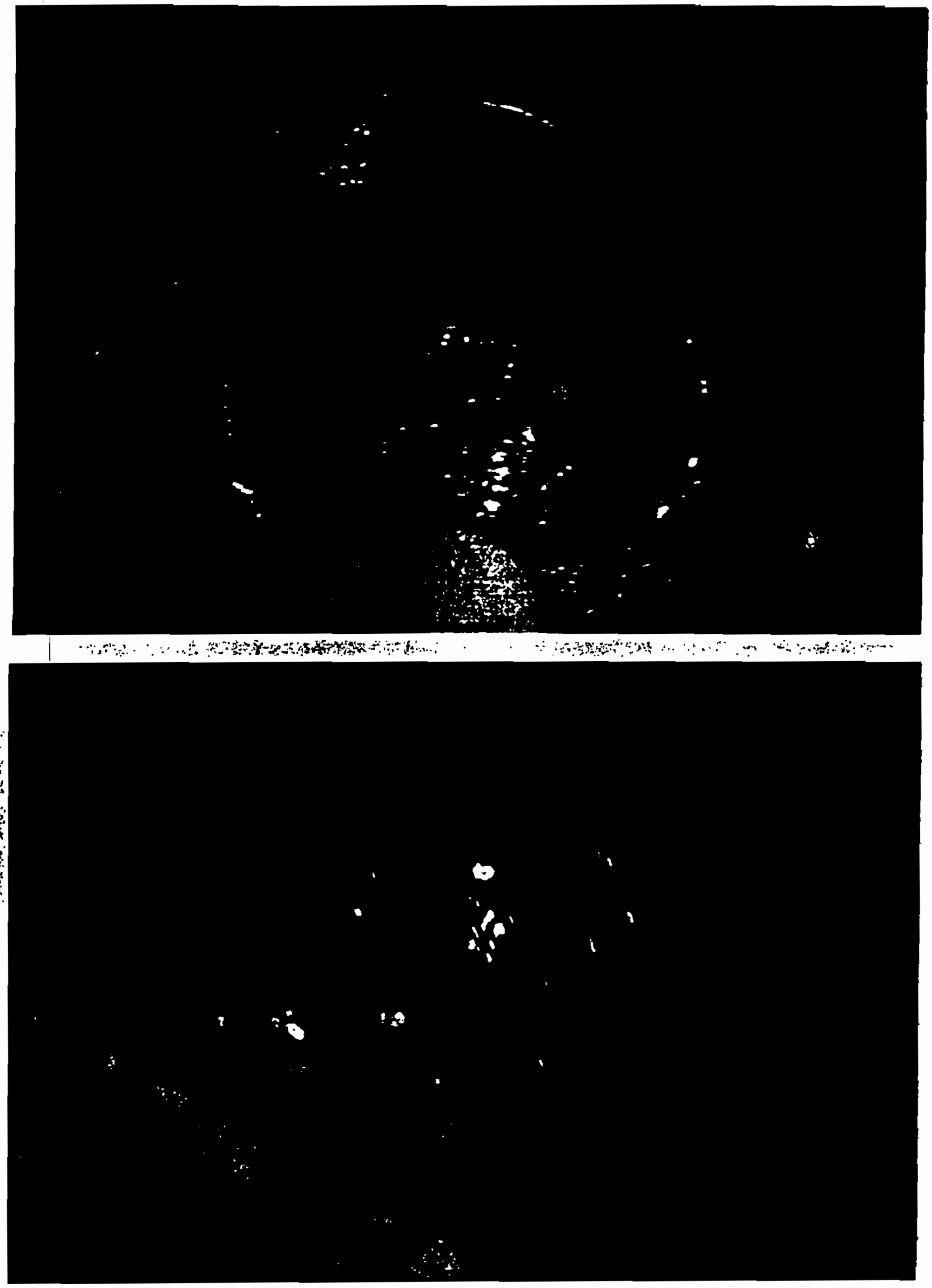

Figure 2. Lesions on 1987 fish No. ONT-13, front and side views. Normal appearance of a brown bullhead mouth is completely smooth, as in the upper right of the top photo. See Table 5 for complete description of lesions observed on this fish.

Lex Maccubbin. In addition, five bullheads were placed on ice and delivered to the Pennsylvania State University Animal Diagnostic Laboratory for histopathological examination by Dr. Hans Rothenbacher.

Four fish tissue samples were prepared for chemical analysis: a composite sample of five whole brown bullheads, a composite sample of five brown bullhead livers, a composite sample of fillets from five brown bullheads, and a composite sample of fillets from five white crappies (Pomoxis annularis). All tissue samples were analyzed for organochlorines, PCBs, and polycyclic aromatic hydrocarbons at the Mississippi State University Chemical Laboratory; and for metals at the Environmental Trace Substance Research Center at Columbia, Missouri.

Because the external lesions on Lake Ontelaunee's brown bullheads appeared to be consistent with those often observed on fish from heavily polluted areas, we requested and secured funding to analyze lake sediments. Four sediment samples were collected for us by the Pennsylvania Department of Environmental Resources on October 7, 1985, using a ponar dredge. Sediment sampling locations are indicated in Figure 1. The samples were sent to the laboratories indicated above and analyzed for the same set of compounds.

Results

Histopathology. The necropsies and histopathological examinations conducted by Dr. Hans Rothenbacher are included in Appendix A. Dr. Rothenbacher identified tapeworm larvae in the livers, kidneys and testes of the fish; liver cirrhosis with marked bile duct proliferation; focal hyperplasia of the gastrointestinal epithelium; and hemorrhagic erosive dermatitis and myositis. Dr. Rothenbacher reported that the external and internal lesions he observed were consistent with chronic chemical irritation resulting in epidermal tumor formation and erosive hyperplastic dermatitis. We forwarded these findings in a September 17, 1985, letter (see Appendix A) to all appropriate State agencies, the Reading Water Authority, and others.

Results of histopathological analyses conducted by the Roswell Park Memorial Institute (see Appendix A, Table A-1) were not received until March 25, 1987. Dr. John Black reported a high incidence (about 21 percent) of liver neoplasms (cholangiomas) in the 24 brown bullhead liver tissues from Lake Ontelaunee. A 40 percent incidence (out of 10 samples) of skin neoplasms was also identified. Dr. Black noted the occurrence of liver parasites in many of the samples.

Chemical Analyses: Sediments. Tables 1 and 2 provide the levels of various trace metals and organic contaminants present in the four Lake Ontelaunee sediment samples, compared to U.S. Environmental Protection Agency "Threshold Contamination Concentrations" (U.S. EPA, 1985). These threshold numbers are theoretical values derived from toxicological data available from established Water Quality Criteria and calculated based on the compound's partition coefficient. The calculated value represents the maximum concentration of the element or compound that could theoretically be present in the average sediment without harming aquatic life. Numerous assumptions are inherent in such calculations (for example, a 40 percent organic carbon content of the sediments is assumed). Because of this, the

Table 1. Levels of metals in Lake Ontelaunee sediments collected on October 7, 1985. Collection locations are shown in Figure 1. All results are reported in ppm dry weight. Numbers in **boldface** represent values exceeding the EPA Threshold Contamination Concentration.[1] Laboratory data sheets are included as Appendix B.

	EPA Threshold[1] Contamination Concentration	Sample Number			
		5	6	7	8
% Moisture		57.7	73.1	68.7	27.9
Arsenic	33	4.1	2.4	2.5	4.9
Aluminum		16,700	13,100	19,800	12,300
Barium		126	110	146	59.2
Beryllium		1.4	1.1	1.1	0.86
Cadmium	31	<0.3	<0.3	0.4	<0.3
Chromium	25	22	19	**25**	19
Copper	136	75.6	22	31	17
Iron		26,800	19,400	30,100	32,200
Mercury	0.8	0.09	0.1	0.1	<0.05
Magnesium		3,140	3,240	4,210	4,330
Manganese		660	539	504	390
Nickel	20	**24**	16	**30**	**26**
Lead	132	45	36	48	21
Selenium		10	<10	20	20
Strontium		16.8	105.	25.1	8.89
Vanadium		17	12	14	12
Zinc	760	107	82.7	144	88.9

[1]The EPA "threshold contamination concentration," derived from toxicological data available from established Water Quality Criteria, represents the maximum concentration of a compound that can be present in sediments without adversely affecting aquatic life. However, the criteria developed from metals have a high associated uncertainty (U.S. EPA, 1985).

Table 2. Levels of organic compounds in Lake Ontelaunee sediments collected on October 7, 1985. Collection locations are shown in Figure 1. All results are reported in ppm wet weight (WW) or dry weight (DW). Laboratory data sheets are included as Appendix B.									
	EPA Threshold Contamination Concentration (DW)	Sample Number							
		5		6		7		8	
		WW	DW	WW	DW	WW	DW	WW	DW
p,p'DDE	28.	0.01	0.02	ND	ND	0.01	0.03	ND	ND
Naphthalene	42	ND	ND	0.01	0.03	ND	ND	ND	ND
Fluorene	28	ND	ND	0.01	0.03	ND	ND	ND	ND
Phenanthrene	56	ND	ND	0.03	0.10	0.02	0.05	ND	ND
Fluoranthrene		0.03	0.07	0.01	0.03	0.06	0.16	0.04	0.06
Pyrene	198	0.03	0.07	ND	ND	0.06	0.16	0.04	0.06
1,2-benzanthracene		0.01	0.02	ND	ND	0.02	0.05	0.02	0.03
Chrysene	460	0.02	0.05	ND	ND	0.03	0.08	0.02	0.03
Benzo(b)fluoranthene		0.03	0.07	0.01	0.03	0.05	0.13	0.02	0.03
Benzo(k)fluoranthene	5,000	0.01	0.02	ND	ND	0.02	0.05	0.01	0.01
Benzo(e)pyrene		0.01	0.02	ND	ND	0.03	0.08	0.01	0.01
Benzo(a)pyrene	1,800	0.03	0.07	ND	ND	0.04	0.11	0.03	0.04
1,2,5,6-dibenzanthracene		0.02	0.05	ND	ND	0.04	0.11	0.02	0.03
Benzo(g,h,i)perylene		0.04	0.10	0.01	0.03	0.06	0.16	0.03	0.04
% Moisture		59.0		69.0		62.0		33.0	

ND = Not Detected

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Table 2. (Continued)

The following compounds were not detected in any of the sediment samples: oxychlordane, heptachlor epoxide, PCBs, p,p'DDD, p,p'DDT, dieldrin, anthracene.

Detection limits (**Wet Weight**)
PCB's: 0.05 ppm
All other compounds: 0.01 ppm

[1]The EPA "threshold contamination concentration," calculated based on the compound's partition coefficient and toxicological data from established water quality criteria, represents the maximum concentration of the compound that can be present in sediments without adversely affecting aquatic life. The calculations assume a 40 percent organic carbon content of sediment. (U.S. EPA, 1985).

[2]Laboratory results were expressed as ppm wet weight. Values were converted to dry weight using the formula:

$$\text{Dry weight concentration} = \frac{\text{Wet weight concentration}}{1 - \frac{\%\ \text{moisture}}{100}}$$

threshold values for metals have a high associated uncertainty. Nevertheless, no formal sediment criteria are available at the state or federal level, and EPA's threshold values offer one of the few available yardsticks with which to compare sediment data.

Levels of the eight organic compounds detected in Lake Ontelaunee sediments for which EPA threshold values are available were several orders of magnitude below the threshold values. Of nine organochlorine pesticides and PCBs included in the analysis, only p,p'DDE was present at all, and only in very low concentrations (maximum 0.03 ppm dry weight). The presence of this compound in the lake's sediments is not unexpected considering the long history of orchards and mushroom houses located in the watershed.

The levels of organic contaminants in Lake Ontelaunee's sediments can also be compared to those in sediments from areas where brown bullheads have been shown to have elevated liver tumor rates. For example, Baumann et al. (1982) documented a 33 percent incidence of liver tumors in three-year old and older brown bullheads collected from the Black River near its junction with Lake Erie at Lorain, Ohio (a highly industrialized area). However, sediment concentrations of polycyclic aromatic hydrocarbons ("PAHs", the main focus of Baumann's study) in the Black River were at least three orders of magnitude higher than at Lake Ontelaunee. PAH levels at the lake are similar to those cited in the literature (Baumann, 1989) from "reference" areas such as Buckeye Lake and Lake Ontario.

EPA threshold contamination values are available for eight of the seventeen trace metals included in our sediment analysis. The chromium threshold value of 25 ppm, unlike other threshold values, was based on guidelines developed in EPA Region V (the Great Lakes area) for designating contaminated vs. non-contaminated sediments. The 25 ppm level was met at Station 7, and chromium levels in the other three samples were not much lower. However, the U.S. Geological Survey (U.S.G.S.) found average chromium levels of 28 ppm in sediment samples collected from Schuylkill River tributaries in 1978 and 1979 (Stamer et al., 1985). Common sources of chromium in the aquatic environment include electroplating and metal finishing industries, municipal sewage treatment plants, iron and steel foundries, chemical plants, tanneries, textile manufacturing, runoff from urban and residential areas, and phosphate fertilizers (Towill et al., 1978; Ecological Analysts, 1981; Langard and Norseth, 1979; as cited in Eisler, 1986). They are also used in cooling waters, in catalytic manufacture, in pigments and primer paints, and in fungicides and wood preservatives (U.S. EPA, 1980). Many of these potential sources exist in Lake Ontelaunee's watershed. Chromium compounds have been found to cause tumors in experimental animals. Further work is warranted to determine whether chromium levels in Lake Ontelaunee are atypical of impounded lakes in this region, and if so, to locate the possible source or sources. It is important to note that no chromium was found (detection limit 4 ppb) in raw or finished water collected from the Reading Water Authority in 1987.

The threshold value for nickel (20 ppm) was exceeded at Stations 5, 7 and 8, with values of 24, 30 and 26 ppm, respectively. Out of 30 stations sampled by U.S.G.S. in 1978 and 1979, 26 had concentrations of nickel of 30 ppm or less (Stamer et al., 1985). Nickel occurs naturally in rocks and minerals and is released into the environment through the weathering of these materials. Anthropogenic sources of nickel in the environment include fossil fuel combustion, and wastewater from alloy casting and plating operations (Taylor et al., 1979; Phillips and Russo, 1978; cited in Rompala et al., 1984). Nickel is listed as a "priority pollutant" by the U.S. Environmental Protection Agency. As with chromium, further investigation into the nickel levels in Lake Ontelaunee's sediments may be warranted.

Arsenic levels in our sediment samples, ranging from 2.4 to 4.1 ppm, were far below the EPA threshold value of 33 ppm. However, the U.S.G.S. survey detected arsenic (detection limit = 0.1 ppm) in only one Schuylkill River tributary out of 23 sampled (Stamer et al., 1985). The highest value found in the watershed was 4.0 ppm in a sample from the mainstem Schuylkill River. Further investigation may be warranted to determine whether arsenic levels in Lake Ontelaunee represent an elevation over background levels.

All copper values in our sediment samples were far below the EPA threshold concentration of 136 ppm. However, sample No. 5 contained 75.6 ppm copper, two to three times higher than the other three lake samples and far exceeding the 40 ppm determined by U.S.G.S. (Stamer et al., 1985) to be a "natural background" level for the Schuylkill River watershed. Sample No. 5 was collected near the dam, in an area where the Reading Water Authority historically applied large doses of copper sulfate to control algae.

Lead levels, ranging from 21 to 48 pmm in our samples, were well below both the EPA threshold level and the U.S.G.S. estimated "background" level of 60 ppm.

Mercury values in the lake samples ranged from not detected to 0.1 ppm, well below the EPA threshold level. However, U.S.G.S. reported that 90 percent of samples collected throughout the Schuylkill River watershed contained less than 0.01 ppm mercury (Stamer et al., 1985). Further investigation may be warranted to determine if mercury levels in Lake Ontelaunee are atypical of impoundment sediments in the region.

Concentrations of zinc detected in Lake Ontelaunee's sediments ranged from 82.7 ppm to 144 ppm. Based on its 1979-1980 sediment sampling throughout the Schuylkill River watershed, the U.S.G.S. estimated that 140 ppm represents a "background" concentration of zinc.

Chemical Analyses: Fish tissues. Levels of trace metals detected in Lake Ontelaunee fish tissues are shown in Table 3, compared with the levels of seven metals in fish collected from over 100 stations around the country in 1984 by the Service's National Contaminant Biomonitoring Program (NCBP). Because the NCBP uses whole fish, only sample 2-1 (a sample of whole brown bullheads) can be directly compared to the NCBP values. Only copper and lead levels exceeded the NCBP's "85th percentile." The copper value (1.2 ppm) is well within the range of residues detected Statewide in 1981-1982 (0.28 to 4.9 ppm). Similarly, the lead value of 0.4 ppm is within the range of Pennsylvania residues of 0.17 to 2.8 ppm.

Table 3. Levels of trace metals detected in fish collected from Lake Ontelaunee on April 24, 1985. All results are reported in ppm wet weight. Numbers in **boldface** represent values exceeding the NPMP 85th percentile. Laboratory data sheets are provided in Appendix B.

	NCPB 1984 85th Percentile	Sample Numbers R5-85-SCFO-___-___			
		2 - 1 Whole Brown Bullhead	2 - 2 Liver Brown Bullhead	2 - 3 Fillet Brown Bullhead	2 - 4 Fillet White Crappie
% Moisture					
Arsenic	0.27	<0.05	<0.05	<0.05	0.06
Aluminum		36.7	4.3	5.3	2.6
Beryllium		<0.005	<0.004	<0.004	<0.004
Cadmium	0.05	<0.05	<0.04	<0.04	<0.04
Cobalt		0.08	0.1		
Chromium		0.1	0.17	0.35	0.17
Copper	1.0	**1.2**	9.10	0.52	0.39
Iron		63.9	372.	10.9	3.7
Mercury	0.17	0.02	0.04	0.04	0.068
Manganese		5.95	1.27	0.33	0.22
Nickel		0.22	0.09	0.16	<0.1
Lead	0.22	**0.4**	0.2	<0.08	0.09
Selenium	0.73	0.23	0.96		
Zinc	34.2	12.5	24.3	4.0	5.06

[1] Seven elements were included in the U.S. Fish and Wildlife Service's 1984 National Contaminant Biomonitoring Program, involving the analysis of residues in whole fish from over 100 stations around the country (Schmitt, C.J. and W.G. Brumbaugh, in press). The 85th percentile of the geometric means for each station is "an arbitrary point distinguishing NCBP stations with 'high' concentrations of elements. It has no meaning with respect to either potential hazards to fishery resources or regulatory statutes" (Lowe et al., 1985, p. 366).

Table 4 provides the results of the organic chemical analysis of fish tissues collected from the lake in 1985, compared to the NCBP 1984 geometric means for many of the compounds. Among the organic contaminants, the NCBP geometric mean values for oxychlordane, heptachlor epoxide and p,p'DDE were met or slightly exceeded by the Lake Ontelaunee brown bullhead sample.

Oxychlordane, a metabolite of the insecticide chlordane, was detected in the brown bullhead sample at 0.01 ppm, a level equaling the NCBP geometric mean. The compound was detected in almost 45 percent of the NCBP stations in 1984. In a survey of contaminants in fish collected by this office from 48 stations across Pennsylvania in 1981-1982, oxychlordane was detected in ten of the samples, at concentrations ranging from 0.01 to 0.03 ppm (Rompala et al, 1984).

Heptachlor epoxide is a metabolite of the insecticide heptachlor; heptachlor is also a minor constituent of the insecticide chlordane. The NCBP detected the compound in fish from 49 percent of the stations. The 1984 geometric mean was 0.01 ppm; the Lake Ontelaunee whole brown bullhead sample contained 0.03 ppm. In this office's 1981-1982 Statewide survey, heptachlor epoxide was detected at only four stations. The highest value detected during the survey (at 0.03 ppm, equal to the Lake Ontelaunee sample) was in a white sucker from Red Clay Creek (Kennett Square, Chester County), a watershed known to be contaminated with a variety of pesticides.

The DDT breakdown product p,p'DDE was detected in the Lake Ontelaunee brown bullhead at 0.26 ppm, slightly exceeding the NCBP 1984 geometric mean of 0.19 ppm. This compound was detected in fish from over 98% of the NCBP stations, and from 88% of Pennsylvania stations during our 1981-1982 survey.

The only PAH detected in the whole brown bullhead sample was phenanthrene at 0.02 ppm. This is two orders of magnitude lower than brown bullheads exhibiting a high incidence of liver tumors from PAH-contaminated Black River, and comparable to the low levels detected in unpolluted Buckeye Lake (Baumann, 1982). PAHs are not included in the Service's NCBP analyses.

1987 SURVEYS

As described above, the histopathological results of our 1985 work, received in 1987, revealed a high incidence of liver neoplasms in Lake Ontelaunee brown bullheads. We were concerned over these findings because the normal incidence of this type of lesion in brown bullheads from unpolluted areas is only 0 - 4 percent. Although viruses have been found to be the cause of some types of tumors in some species of fish, no virus has yet been identified in connection with liver tumors in brown bullheads; rather, the cause is thought to be the presence of chemical carcinogens in the environment. Chemical analysis of fish and sediments collected by this office in 1985 had failed to detect any organochlorines, PCB's, polycyclic aromatic hydrocarbons, or metals at levels that would be expected to cause such a high incidence of liver lesions. However, we remained concerned that a carcinogen or carcinogens from some other family of chemical compounds not included in our analysis might be present in the lake, that carcinogens present in the fish tissues had been metabolized into

Table 4. Levels of organic contaminants detected in fish samples collected from Lake Ontelaunee on April 24, 1985. All results are in ppm wet weight. Laboratory results are included as Appendix B. Residue levels in **boldface** represent values exceeding the NCBP geometric mean.

	NCBP 1984 Geometric Mean	Sample Numbers R5-85-SCFO-__-__			
		2 - 1 Whole Brown Bullhead	2 - 2 Liver Brown Bullhead	2 - 3 Fillet Brown Bullhead	2 - 4 Fillet White Crappie
% Moisture		76.2	73.2	78.0	79.8
% Lipid		5.1	2.3	1.48	0.12
Oxychlordane	0.01	**0.01**	ND	ND	ND
Heptachlor epoxide	0.01	**0.03**	ND	ND	ND
Total PCBs	0.39	0.14	ND	ND	ND
p,p'DDE	0.19	**0.26**	ND	0.04	ND
Dieldrin	0.04	0.01	ND	ND	ND
p,p'DDD	0.06	0.03	ND	ND	ND
p,p'DDT	0.03	0.01	ND	ND	ND
Phenanthrene		0.020	0.020	0.01	0.01

ND = Not Detected

The following compounds were not detected in any of the fish samples: naphthalene, fluorene, anthracene, fluoranthrene, pyrene, 1,2-benzanthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, 1,2,5,6-dibenzanthracene, benzo(g,h,i)perylene.

[1]The U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program looks for organochlorine and PCB residues in whole fish collected from over 100 stations natiowide (Schmitt et al., in press).

undetected compounds, or that our limited sampling had simply failed to locate contaminated areas. We discussed the circumstances of the case with Dr. Eric May of the University of Maryland, who agreed to assist us in an expanded study at Lake Ontelaunee to determine if viral agents could be responsible. Work was initiated immediately.

Methods

On April 21, 1987, this office cooperated with the Pennsylvania Department of Environmental Resources (DER) and the PFC to obtain new brown bullhead samples. PFC personnel set trap nets in Lake Ontelaunee in the same areas where collection efforts had yielded brown bullheads in 1985 (see Figure 1). FWS and DER personnel took all brown bullheads as they were brought in from the lake, and transported the fish live to the Reading Water Authority filtration plant, where laboratory facilities had been made available to us. The fish were processed immediately.

Each brown bullhead was euthanized by severing the spinal cord. Lengths, weights, and observations of external lesions were recorded on data sheets. A summary of these observations is presented in Table 5. Next, each fish was examined internally, and any abnormalities were noted. Small (approximately 2 mm wide) pieces of oral and skin lesions were removed by flame-sterilized (Bunsen burner) instruments and placed in a media containing calf embryo cells, provided by Dr. Frank Hetrick of the University of Maryland. Additional 2 mm pieces of tissue were placed in a preservative provided by Dr. May. Pieces of the liver, containing abnormal areas if possible, were also collected.

Nineteen brown bullheads were processed in the above manner. Liver and skin samples from the first 10 were sent to Dr. Hetrick (each tissue type in a separate vial of media). Liver and skin samples from all 19 fish were sent to Dr. May in the preservative he provided. No samples were collected for chemical analysis during the 1987 work.

Results

Out of the 23 brown bullheads processed at Lake Ontelaunee in 1987, 14 (or 60 percent) had obvious external, tumor-like lesions on the lips. In many cases, both the upper and lower lips were fully involved with these "tumors." The largest of the lip lesions measured 4 cm by 2.5 cm, forming a huge reddish/tan mass on the fish's upper lip (see Figure 2). One fish also had an especially notable lump on its head, measuring 1.8 cm by 2.4 cm. Livers ranged from normal in appearance to asymmetrical in shape or mottled in color. Parasites were common on the livers, as they had been in the 1985 samples.

Appendix C provides the complete results of Dr. Eric May's histopathological examination of tissues collected during the 1987 survey as well as his opinion of lesions observable in slides originally processed by Dr. John Black from the 1985 collection effort. Dr. Frank Hetrick's report on the attempt to isolate a virus is also included in Appendix C. Because of the completeness of these reports, we consider them to be an integral part of the "results" section and recommend that the reader review Appendix C in its entirety. To summarize, however, Dr. May theorizes that

Table 5. Lengths and weights of brown bullheads processed for histopathology and viral work in 1987, with gross observations noted by FWS field biologists.			
Sample No.	Length (mm)	Weight (g)	Gross Lesions Observed
ONT-2	366	690	Several raised lesions observed on lips and surface of skin.
ONT-3	310	418	Inflamed, open lesions below hinges of jaw
ONT-4	330	522	Numerous discolored lesions on lips.
ONT-5	330	545	Numerous raised lesions on lips; one barbel missing.
ONT-6	310	450	One raised lesion on lower lip.
ONT-7	330	525	Small lesion on upper lip.
ONT-8	310	400	Numerous small lesions on lips; one swollen and discolored area on lower lip.
ONT-9	310	483	Small (3 mm diam.) raised lesion on top of head; yellow spot on left gill rake; raised lesion at lower left inside corner of mouth.
ONT-10	260	225	Large (18 x 24 mm) raised lesion on top of head.
ONT-11	280	268	One small nodule on lower lip.
ONT-13	387	710	Mouth fully involved in huge reddish/tan lesions; one measured 4 x 2.5 cm. Also massive yellowish tumor on tongue. Two reddish/white sores, approx. 15 mm in diam., on left side; one yellowish lesion, 7 mm in diameter and raised 1 mm above skin, on left side; one burned barbel.
ONT-14	345	682	Raised lesions on lips; large scar on roof of mouth; one missing barbel.

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Table 5. Continued			
Sample No.	Length (mm)	Weight (g)	Gross Lesions Observed
ONT-15	315	410	Entire lower jaw and inner rim of jaw involved in lesions. Large (3 x 15 cm) lesion on roof of mouth. Three white skin patches and one dark skin patch on left side.
ONT-16	335	518	None observed.
ONT-17	359	565	None observed.
ONT-18	315	543	One red spot (not raised) on lower lip.
ONT-19	325	467	Large lesion on upper and lower lips. Tail and lower fins tattered (not due to net damage).
ONT-20	275	250	None observed.
ONT-21	285	300	None observed.

the cholangiomas reported by Dr. Black may be caused by parasites observed in the livers, and that a viral agent may be involved in the high incidence of papillomas. Copper sulfate, possibly present in the sediments, may be a factor in inducing the observed skin lesions.

DISCUSSION

The scientific literature has contained reports and discussions on incidents of tumors in feral fish for many years. Lucke' and Schlumberger (as cited in Baumann, 1989), described epitheliomas on the lip and mouth of brown bullheads from the Delaware and Schuylkill Rivers near Philadelphia in 1941. From their description of the uneven distribution of the phenomena within various reaches of the river, Baumann (1989) concludes that a chemical etiology may have been involved. Interest in the use of fish tumors as "early warning signals" of environmental contamination has increased since the 1960's, when an international epidemic of liver cancer in hatchery-reared rainbow trout led to the discovery that a mold growing on peanuts used in trout food produced aflatoxins (Morell, 1984). Aflatoxins have since been identified as one of the most potent carcinogens known.

Sonstegard (1977) necropsied over 50,000 fish from the Great Lakes and found epizootics (epidemic incidence) of tumors in carp (Cyprinus carpio), goldfish (Carassius auratus), carp x goldfish hybrids (Cyprinus carpio x Carassius auratus) and white suckers (Catostomus commersoni). In many cases, the high tumor incidences were clustered around polluted areas. Brown el al. (1973) compared fish from the polluted Fox River in Illinois to unpolluted Canadian waters (Lake of the Woods, Ontario) and found a much higher tumor incidence in Fox River fish vs. fish from the same species at Lake of the Woods. Black (1983) established an apparent cause-and-effect link between contaminated sediments and skin tumors on brown bullheads; he painted a laboratory population of brown bullheads with an extract of PAH-laden Buffalo River sediments, and observed the development of epidermal hyperplasia and neoplasms within 12 months. Black used the same technique on mice, and skin cancer developed almost immediately (Morell, 1984).

The brown bullhead is frequently selected as an indicator organism in fish tumor/pollution studies because it is fairly ubiquitous in the eastern United States, abundant, and susceptible to hepatic tumor development. Further, brown bullheads are capable of surviving in low-oxygen, polluted environments, resulting in long-term exposure to contaminants (Baumann et al., 1982). Because of the growing body of scientific literature describing skin and liver lesions in this species and their co-occurrence with carcinogenic chemicals in sediments, the discovery of an epizootic of liver tumors in a brown bullhead population immediately raises a suspicion that a carcinogen is present; skin neoplasms, although of concern, are considered to be less conclusive. At Lake Ontelaunee, skin neoplasms have been verified in the brown bullhead population, but observed liver lesions may be due to invasion by parasites rather than a chemical etiology (see Appendix C). Further complicating interpretation of this situation is PFC Area Manager Mike Kauffman's observation that brown bullheads with the severe skin tumors are observed only in the spring; fish collected in the fall are normal in appearance.

Although only a limited number of environmental samples from Lake Ontelaunee has been analyzed for chemical contaminants, no sample has yet revealed an alarming level of carcinogens typical of areas known to have a high incidence of brown bullhead tumors. Concurrent with sediment and fish tissue sampling, State agencies have analyzed finished water from the Reading Water Authority plant for priority pollutants, and found no contaminants present beyond acceptable levels. Limited viralogical work conducted in 1987 likewise failed to identify a viral agent that could be responsible.

In numerous discussions with State agencies and researchers in the field, a variety of hypotheses have been suggested to explain the brown bullhead tumor epizootic at Lake Ontelaunee. Some of these include:

1) It has been suggested that brown bullheads may be genetically susceptible to tumor formation. If this is true, then perhaps the inbreeding resulting from the relatively "closed" nature of Lake Ontelaunee's brown bullhead population may have simply created a genetic tendency for tumor formation.

2) The Reading Water Authority has used large quantities of copper sulfate in the past as an algicide, concentrating application to a relatively small area of the lake. If this area corresponds to the preferred habitat of the brown bullheads, the fish are likely spending a large amount of time in direct contact with copper sulfate-laden sediments. Chemical-related stress may then play an immuno-suppressive role, allowing viral agents to trigger tumor formation.

3) Chemical carcinogens not yet included in chemical analyses may be present. This would be very difficult to identify without expensive testing.

4) Sediment sampling conducted to date may have missed "hot spots" of contamination.

The brief surveys conducted at Lake Ontelaunee have been inconclusive, in that no cause for the brown bullhead "tumors" has been identified. However, in researching this case, we have become aware of a number of similar incidents in New York State - lakes considered to be relatively pristine, where brown bullheads have skin and liver tumors, but no pollutant has yet been detected at levels significant enough to be the cause of the lesions. It is clear that much additional research into these cases is needed in order to determine the cause of these phenomena; the implications for the health of fish, wildlife and human populations; and if man's activities are at fault, how to take corrective action.